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Using WeBWorK in an Online Course Environment

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Abstract

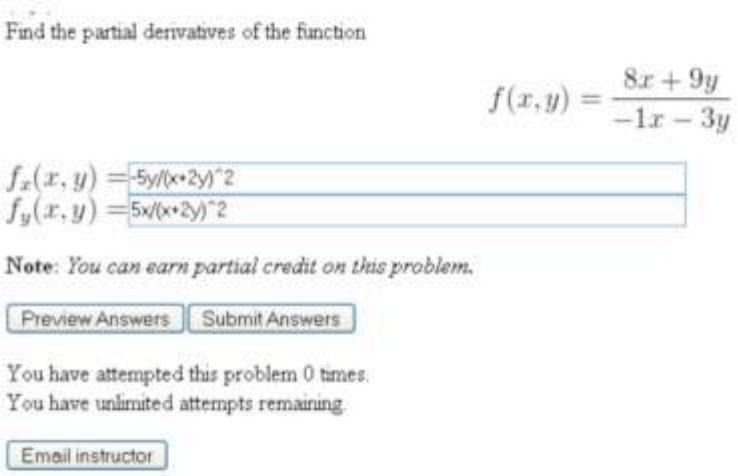
WeBWorK is a free, open source, Web-based, interactive mathematics homework system used to individualize and automate grading of mathematics homework assignments. Previous and ongoing research indicates that students who use WeBWorK stay on task longer than students who use traditional paper and pencil methods and often score higher on pre-test and post-test experiments. In this report we connect the use of WeBWorK to an online teaching-learning environment and address some of the benefits and issues students and instructors will have when using WeBWorK. We include some "do and don't" suggestions especially for instructors to help make the program more user-friendly for themselves and for their students.

Key Words: Web-based homework, WeBWorK, homework

Introduction

Since the introduction of rudimentary "drill and practice" teaching machines designed to have students learn the basic facts of a subject (Pressey, 1926), we have seen a long procession of more and more mechanically and electronically sophisticated "machines" enter the teaching-learning setting. Research on the effectiveness of such apparatus is mixed for use in the traditional classroom; although WeBWorK, one of the modern descendants of Pressey's machine, has been shown to be an efficient tool for homework when used as an integral part of a mathematics course in a classroom setting, we extrapolate its use here to the e-learning environment of online courses. With no pretense of doing justice to the short but rich history of machine-assisted learning systems, we mention in passing that with the invention of the computer, Pressey's "machine" soon developed into an electronically sophisticated instructional tool, often in the form of "computer assisted instruction." With the appearance of the internet, "e-learning" took its place in the teaching-learning communities of schools, academe, and industry. Almost all new college students in the United States have used a personal computer by age 18 and approximately half of entering first-year students have used the internet; the other half will be introduced to the internet when

they get to college (Pew, 2002). In this paper, we address some of the issues faced by college mathematics instructors who are, or will be, teaching an online mathematics course and: (a) have decided to use WeBWorK for managing the homework assignments as well as (b) are new to the web-based WeBWorK interface. Thus, here we concentrate mostly on how to incorporate WeBWorK into a mathematics course and illustrate whenever appropriate some, but certainly not all, of the features of this sophisticated descendant of Pressey's machine. We conclude this introduction by illustrating, in Figure 1, the most salient feature of WeBWorK: the program can interpret student responses written in mathematical notation.


Find the partial derivatives of the function

$$f(x,y) = \frac{8x+9y}{-1x-3y}$$

$f_x(x,y) =$ -5y/(x+2y)^2

$f_y(x,y) =$ 5x/(x+2y)^2

Note: *You can earn partial credit on this problem.*

Preview Answers | Submit Answers

You have attempted this problem 0 times.
You have unlimited attempts remaining.

Email instructor

Figure 1(a): A typical WeBWorK question and student answer

Entered	Answer Preview	Result
(-15*y)/[(x+3*y)^2]	$\frac{-15y}{(x+3y)^2}$	correct
(15*x)/[(x+3*y)^2]	$\frac{15x}{(x+3y)^2}$	correct

All of the above answers are correct

(1 pt)
Find the partial derivatives of the function

$$f(x,y) = \frac{8x+9y}{-1x-3y}$$

$f_x(x,y) =$ -15y/(x+3y)^2
$f_y(x,y) =$ 15x/(x+3y)^2

Figure 1(b): WeBWorK response to student's entry

How Important is Homework?

Many studies have already established the importance of homework, especially for the advanced cognitive development expected in high school and college mathematics (Cooper, 1989; Cooper, Lindsay, Nye, & Greathouse, 1998; Warton, 2001). Homework is an activity related to motivation, mastery of material, and to achievement (Keith & Cool, 1992). It is also clear from the research that homework is a necessary but not sufficient prerequisite for satisfactory achievement on exams (see, for example, Peters, Kethley & Bullington, 2002; Porter & Riley, 1996). However, the role of homework in student achievement is only partly understood and research continues on the topic.

Within the liberal arts tradition at U.S. colleges, the primary purpose of homework in college mathematics is to support the development of knowledge of facts, connections, procedures, and reasoning for later use in more advanced mathematics or in applications to life (e.g., finance). The method for achieving this goal has traditionally been through paper and pencil homework practice with facts and concepts. Exercise sets in most college mathematics textbooks offer drill practice with facts followed by practice with applications, and a brief interaction with abstract concepts. Many texts end an exercise set with mildly non-routine problems aimed at encouraging students to deeper reflection on concepts and their relationships. For a variety of reasons, from pressure to "cover" a proscribed collection of chapters in

such textbooks to the personal epistemologies of students and instructors, the usual practice in college mathematics teaching is to assign problems mostly from the first two categories (drill and application) and few from the third (concepts). Though there are efforts to rewrite college mathematics textbooks along the lines of the reform of calculus in the United States (e.g., Connally, Hughes-Hallett, Gleason, Chiefetz, Flath, Lock, et al., 2004; Kime & Clark, 2001), our discussion here is directed to those working in traditional as well as reform settings, with the latter including the new trend of online courses.

About WeBWorK

WeBWorK is an efficient, free, open source, Web-based, interactive mathematics homework system used to automate the instructional tasks of assigning, presenting, correcting, and recording mathematics homework of the drill and application types. That is, WeBWorK is for closed-ended mathematics problems that have solutions that can be expressed in a finite number of ways using standard mathematics notation. Research at colleges and secondary schools suggests that WeBWorK is an effective learning tool when integrated explicitly and consistently as part of a mathematics course. The mathematics achievement (as measured by written exams) among students who use WeBWorK for homework assignments is as good as, and often better than, achievement among students in the same courses who completed traditional paper-and-pencil homework assignments. WeBWorK is not a tutorial program; it grades items and records students' scores. Those items can be structured by the instructor as homework, quizzes, tests, worksheets, or other activity. The program also keeps track of students' solution attempts so the instructor can keep apprised of student efforts. Simply put, WeBWorK is an electronic homework helper that allows the instructor to concentrate less on the labor-intensive task of checking students' homework and more on stimulating instructional planning and course activities.

WeBWorK is currently used in more than 100 universities and community colleges with an estimated 80,000 students. Unlike some other (commercial) programs that have a homework component as part of the larger system, WeBWorK was developed explicitly and solely for accepting answers in mathematical notation. Yet, its versatility is such that it is also being heavily used in physics and other science classes, and the program could easily be adapted to other subjects.

In WeBWorK the student first prints out a copy of the assignment, then works on the assignment as in the traditional pencil-and-paper method. Once items are completed, the student enters the answers in WeBWorK. The program gives the student an immediate response on each problem stating if the answer is correct or not. If the answer is not correct the student is allowed another try, and another; there is no limit on the number of tries unless the instructor limits the number of tries as one might, in the case of a quiz. WeBWorK keeps track of how many solution attempts a student submitted, the number of correct answers, and the number of tries it took a student to get to the answer submitted.

Some instructors at colleges using WeBWorK report that the program motivates students to do more homework than they would ordinarily do in the traditional paper-and-pencil format. The University of Rochester, for example, reports that more than 90% of their students complete WeBWorK assignments.

How Students Use WeBWorK

WeBWorK is simple to use for the student. Students go to the course WeBWorK URL, log in with username and password, choose the problem set that has been assigned and begin to do homework. The problems are unique to each student, with built-in parameters that are randomized by WeBWorK using the student's id number as the randomization seed. If the student does not complete the assignment in one sitting, the student can log out and restart at exactly the same place at next log in: the problem-set's randomized parameters do not change from session to session.

Students can work in groups on the same assignment because WeBWorK gives each students the "same" problem but with different parameters. One student will be asked to solve the quadratic equation $2x^2 - 15x - 8 = 0$, another will get $2x^2 - 3x - 5 = 0$.

How to Use WeBWorK as an Instructor

One of the first things an instructor new to WeBWorK should do is get some practice using WeBWorK as a student (more on this below in Suggestion 2). An instructor logs on to WeBWorK with a number of homework management privileges. We do not delve into these in any

specific manner here since this paper is intended only as a collection of sign posts on how to use WeBWorK, not a training program. A detailed online "how-to" source for first-time and repeat users of WeBWorK is available through the Web site *http://bosna.natsci.csulb.edu:8888/webwork2/*. Many universities using WeBWorK offer professional development WeBWorK workshops. Frequently, instructors who attend the workshops, especially those who are going to use WeBWorK for the first time, will get some technical telephone support.

Through the WeBWorK interface an instructor can perform a host of tasks ranging from setting due dates to changing passwords to limiting the number of tries a student gets on each problem, to creating, coding, and adding new problems to the database. However, the first-time user of WeBWorK is well-served by the existing national problem library: it contains thousands of problems to choose from for courses from beginning algebra to differential equations.

Among the "do and don't" suggestions below we also offer a number of references where instructors new to WeBWorK can learn more about the program. Among the technicalities that we do not get into here but that are well-addressed in the references provided here, are how to:

- Create a problem set
- Select and add problems to a set
- Edit an existing problem set
- Copy a problem set from another instructor's class
- Assign a problem set by making it visible to students
- Set up scoring parameters for a problem set
- Send email to students
- View student(s) progress
- Act as a student
- Change set data for an individual student
- Change a password
- Remove or change student status
- Write new problems or edit existing problems

Suggestions for Using WeBWorK

Based on research results and experience using WeBWorK, we offer the following set of suggestions to instructors who will use WeBWorK for the first time.

Suggestion 1: *Depend on your local WeBWorK administrator for technical support.*

There are several levels of authorization and responsibility in the WeBWorK system. The most authoritative is the national "WeBWorK Team," a handful of mathematics and computer experts around the country, mostly university mathematics professors, who created and regularly improve the program. The national WeBWorK Team is the gatekeeper of the program at the national level (as of this writing, version 2.3.2 is out).

Locally, your university WeBWorK administrator is the gatekeeper of the WeBWorK hardware and software, and has the authority to make changes, answer technical questions, and fix "bugs." The research on human interactions around learning technology supports the following suggestion: If you are using WeBWorK through an agreement with another institution, find out who the local WeBWorK expert is and open a clear channel of communication with that person. Be sure to read some of the reference information about WeBWorK before you begin this communication. The WeBWorK administrator will need a spreadsheet of your class members and id numbers, but some additional information is in order: how and why you plan to use WeBWorK, how many students are involved, course numbers, dates, etc. This paves the way for an efficient and smooth working relationship. Also, be sure to negotiate a back-up method for contacting your local WeBWorK administrator in case the primary method fails. For example, if the primary contact method is email and the server goes down, have a contact phone number for the local WeBWorK administrator!

At the third level, as an instructor you have control of your WeBWorK class(es) and have a wide enough range of authorization to make changes — technical and not-technical — to the WeBWorK part of your own course. In "Instructor Mode" one does not have to be a coding expert to keep the administrative part of homework assignments current and correct. Nonetheless, help is available for just this sort of thing through the Web sites given below. Choose the level of WeBWorK expertise that is most comfortable for you in making WeBWorK an integral part of the course.

Suggestion 2: *Plan to spend at least three hours on the steep side of the learning curve to get familiar with the program before the semester begins.*

There are several ways to do this. Some are more appropriate for full-time faculty whose departments may have funds to allow them to attend live training sessions. Other ways are more accessible to adjunct faculty who may face more challenges in getting the time or professional development funds for attending workshops. As with mathematics learning, after the initial investment of energy to come up the steep side of the logistic curve, regular continued exploration about WeBWorK will improve your instructional success in using it. We list several ways to tackle the steep part of the learning curve and to continue learning here, starting with the most accessible.

2.1. *The interactive WeBWorK users group* at http://65.206.22.46/moodle/ is a must for both experienced and novice WeBWorK instructors. On the left side of the screen you will see the message: "If you are new to WeBWorK start here." Click that link and you have begun your steep climb. Typical questions for beginners you can get answers to at this site are how to: (a) set up your course; (b) add or drop students; (c) build a problem set; (d) modify due dates; (e) change passwords; (f) post messages for the entire class; and (g) send emails to the entire class or an individual student, including how to generate a form email that sends a different email to each student containing that students' grades.

2.2. *Explore the many WeBWorK installations at other universities*. The national WeBWorK Team hosts a site with links to many other university WeBWorK information sites: http://math.webwork.rochester.edu/docs/sites/courses/links_to_courses.html. Some, not all, have excellent instructions on how to use WeBWorK as a student and as an instructor.

2.3. *Download the PowerPoint program "WeBWorK Workshop"* from http://bosna.natsci.csulb.edu:8888/webwork2/. This is an easy-to-follow presentation of the basics about how to use WeBWorK as an instructor.

2.4. *Before you allow students to use the program ask your local WeBWorK administrator to set up a practice course* that will allow you to explore both "as student" and as "the instructor." You probably will spend very little time in student mode because WeBWorK is easy for students to use. To get an appreciation for the flexibility WeBWorK offers students, visit https://webwork.dartmouth.edu/ and click on "Demo Course." You will spend more time in instructor mode, of course, because

WeBWorK has so many features. Explore and change things to see what happens. You will not damage the WeBWorK program globally from a practice class. So explore away. The instructor (and students) use copies of both the program files and problem sets. The original files are safely stored on the cavernous servers of the "WeBWorK team" and cannot be modified by changes you make locally.

2.5. *Attend a WeBWorK training workshop*. These are usually offered at the national and often at some of the regional MAA conferences. For more details, see http://www.maa.org/webwork/.

Suggestion 3: *As important to preparing yourself to use WeBWorK is to prepare your students.*

We found a great deal of positive influence on student use and persistence with WeBWorK when we provided an introductory half-hour of WeBWorK activities for students to complete in a computer lab. The activity included a few minutes of hands-on practice logging into and moving around a WeBWorK practice assignment followed by four problems for students to complete. In an online course environment, we suggest a tutorial, such as a PowerPoint Web presentation that provides students with (1) the correct URL, (2) the log on process (username and password), and (3) once in the program, a "Problem Set 0" that involves students in using the basic functionality of WeBWorK to print a problem set, preview answers in mathematical form, submit answers, and review their work. Many of the WeBWorK installations around the country have these tutorials available to their students.

Suggestion 4: *Cultivate a view of cautious optimism about WeBWorK*.

Research on WeBWorK suggests that student achievement in courses that use WeBWorK is highly correlated to a supportive but cautious attitude toward WeBWorK on the part of the instructor (see, for example, Hauk & Segalla, 2005). In fact, much research has indicated that an attitude at either extreme (e.g., hate to best-thing-since-sliced-bread) can interfere with optimal use of any instructional tool (Mumtaz, 2000). Simply put: on a zero to ten scale, with zero for loathe and ten for awestruck, an instructor attitude between four and eight will yield the best results in terms of student willingness to work with WeBWorK. For example, through doing problems in "student-mode" an instructor can build an awareness of the foibles of WeBWorK and can capitalize on the shortcomings of the interface to generate

online discussion of the nature of mathematical representation and communication. Similarly, familiarity with the types of drill and procedural items in the Problem Library opens the way for online discussions or student-team-prepared presentations about complex applications or conceptual foundations. These types of engagement with mathematics (representing, communicating, problem-solving, connecting, reasoning) are key aspects of deep understanding of mathematics (National Council of Teachers of Mathematics, 2000). WeBWorK items can start student activity in these areas and follow-up assignments can extend and deepen their learning (e.g., see Suggestions 12 and 13, below).

Suggestion 5: *Anticipate and be ready for student concerns about WeBWorK itself.*

You will experience challenges and small confusions yourself as you familiarize yourself with the student view of WeBWorK. Also, you will learn more about the initial challenges at the sites we recommended in Suggestion 2. A typical student puzzlement likely to find its way into your email is: "But I did the problem right and it told me the answer was incorrect." Although it may be true that the student has uncovered a glitch in the program — unlikely but possible — it is more likely that this is a syntax issue. For example, if the student submits $x+5/x$ but the answer is $(x+5)/x$, WeBWorK will indeed say it is incorrect. An effective suggestion to the student is: "Before you submit your answer, use the 'Preview Answer' button to check that what you entered in the answer window — in calculator notation — matches what you mean to say." As in any online learning environment, additional student questions to anticipate include:

- I forgot my password, how do I find out what it is?
- Why can't I see the correct answer like in the textbook?
- Can you extend my due date for Set 5?
- How can I see my grades so far?

Suggestion 6: *Have students print out a hard copy of their (individual) assignment.*

Trying to do mathematics in front of the computer screen is not conducive to concentrating on a problem. The "live" though silent monitor screen, which may slip into screensaver mode, can imbue a sense of impatience that may cause some anxiety for students. It is also tempting to use the computer for other purposes as a break from working on a problem, (e.g., "surfing the net"). We have found that

the most complete interaction with the mathematics comes when students print out and work the problems on paper, as they would any other mathematics assignment, and use WeBWorK only as the source and as the instant grader of their work.

Suggestion 7: *Work the problems first.*

Ideally, the instructor has worked out each problem chosen for a problem set before assigning it to the students. We say ideally because our experience has been that three in ten instructors make it a habit to do this. The payoff for them is that they can (1) anticipate mathematical and syntactical errors, and (2) it enables them to post hints for each problem in the "Set Info" window.

Suggestion 8: *Periodic meetings, virtual or face-to-face, with other faculty members using WeBWorK can be very helpful.*

As noted above, instructors can join the national discussion among WeBWorK users. Depending on the use of WeBWorK at your institution, consider joining or creating a local faculty wiki or "Discussion Board." If available, a faculty (and student!) users manual can answer a lot of questions before they get to the instructor (e.g., a wiki Web site that both students and faculty contribute to locally). The manual might be a short and to the point read-only document. Whatever mechanism is used, include a section with answers to Frequently Asked Questions (FAQ).

Suggestion 9: *Set course policies about communication to facilitate student autonomy.*

Online instruction is a bit of a misnomer in that teaching in an online environment often involves other, "offline," methods of communication. There are several ways for students and instructors to communicate through and around WeBWorK.

9.1. *Web:* Based on your experiences starting to work with WeBWorK and on your familiarity with the students at your institution, create a page of links to WeBWorK resources you think your students will find useful — then you can respond to many questions about logistical issues by pointing them to the Web page with the answer (instead of typing up the answer) in the reply email you send.

9.2. *Email:* While doing their homework, students will take advantage of the "Email Instructor" feature, as they should. Even though as

an online course instructor you will be on the net more so than instructors teaching traditional classes, it is a good idea to set some email priority rules to keep the number of emails manageable. For example, you might let students know in your posted course policies that when you receive email questions the first thing you ask yourself is: Is the answer to this question already available to a diligent student? Encourage students to exert at least five minutes' effort to answer their own question through the three most likely resources: the textbook; emailing, calling, or text messaging a classmate; the WeBWorK help page you set up (see Suggestion 9.1 above). Additionally, in the syllabus or course policies, you can mention that you might send a very simple email in response to questions that are answered by these resources. Anything from "Read Section X.Y of the text and try again" to "My suggestion is to spend 30 minutes on this on your own by first reading Section X.Y, then working the examples through on paper for yourself. If, after you have completed that and have come back to your WeBWorK assignment, you still have a question, please email me again with the details of your question."

9.3. *Telephone/messaging:* Telephone and text messaging policies can follow similar rules to those for email, above.

9.4. *Online discussion:* Have a WeBWorK-dedicated thread as a "Discussion Forum" where asynchronous electronic conferencing allows students to post and answer messages. Our experience indicates that students may benefit from immediate communication by messaging or calling each other with small issues while research certainly suggests that such peer-to-peer reliance can be very good for student learning. However, ask students to post a summary of the problem and how they resolved it (e.g., with the help of a peer) on the Discussion Forum as an aid to students who may have the same or similar issue in the future.

9.5. *"Set Info:"* If you can anticipate some questions, place some general hints for that assignment using the "Set Info" part of WeBWorK– it will appear on the right hand side of the screen (see Figure 2).

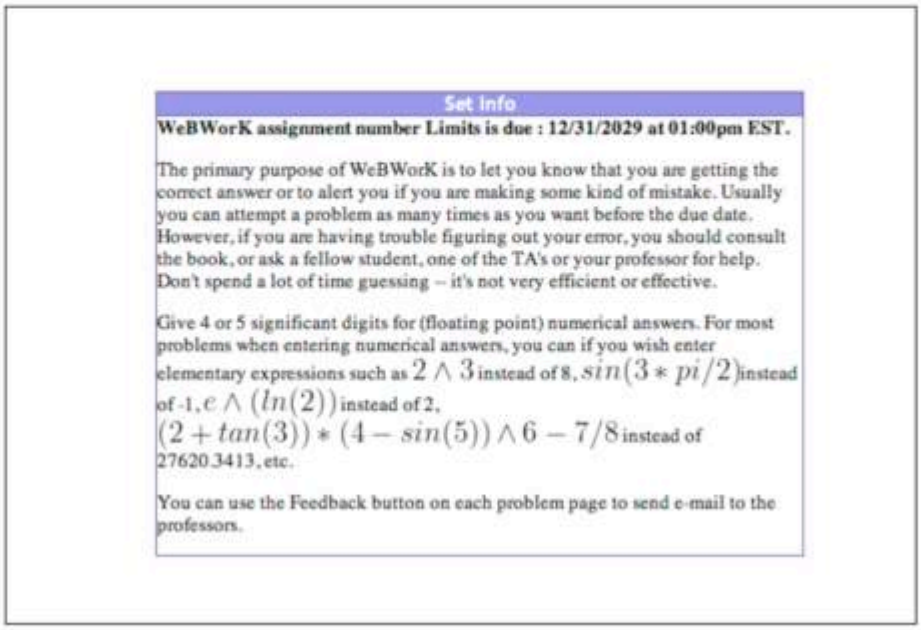


Figure 2: Set Info Screen

Suggestion 10: *Prepare for reluctance to learn new technology.*

Some people generally resist change. Be aware that students may not be as enthusiastic as the instructor is with the way the course is delivered and, worse, that their homework assignment is evaluated by a machine! Many students who feel forced to take an online course may have some (justified) reluctance to engage in the delivery method. Recognize this and deal with it in appropriate ways. Insight into the challenges of the first-timer experience as online instructor can be found in Conrad's (2004) article. Though many potential remedies are available in books and articles, two books we have found particularly useful along these lines are among the large collection by Palloff and Pratt (2003, 2005).

Suggestion 11: *Set up grading to encourage WeBWorK completion.*

Studies show that WeBWorK keeps students on task longer. In one study, this translated into the fact that low-performing students using WeBWorK achieved a higher total gain in (post-test minus pre-test) scores than low-performing students using traditional paper-and-pencil

homework (Segalla, 2006.) Consider this fact when setting up your grading scale. Perhaps making homework count as heavily as, say quizzes or an exam, will support students to stay on task longer.

Suggestion 12: *Explore ways to use WeBWorK to identify, explain, and correct conceptual errors.*

WeBWorK is flexible, but it is not an artificial intelligence program that can pinpoint where a particular student or group of students made a conceptual error. One way to capitalize on the information WeBWorK gathers on student effort is to first examine the WeBWorK spreadsheet to see how many students in the class missed (or retried a great deal) a problem containing a particular concept. Prepare a subset of WeBWorK problems that scaffold up to the big idea, perhaps as a follow-up activity or quiz. You might also recommend some tutorials and Web sites to students through the "Set Info" feature.

Suggestion 13: *Motivate course discussion through challenging WeBWorK items.*

The instructor receives student performance information dynamically in the form of a spreadsheet and can easily see how students performed individually and as a class. As noted above in Suggestion 12, the instructor can identify homework problems that may need to be discussed as a class. A problem that shows a large number of tries and has a considerable number of wrong responses is one to consider for an enhanced presentation or "Discussion Board" activity. Perhaps even extend the deadline for completion of that particular item in WeBWorK to allow time for online interaction around the problem.

Suggestion 14: *Be familiar with "the buttons."*

There are several important "buttons" in WeBWorK available to the student to communicate with the instructor or to check their work before they submit it for a grade. Depending on the version of WeBWorK you are using, these buttons may change name and location on the screen, but wherever they are, the "Help," "Feedback," "Print a hard copy," and "Preview" buttons are important to the successful use of WeBWorK by the students. Spend some time on encouraging your students in their use. The flipside is that the instructor needs to take the time and trouble to tailor these helpful buttons to their local needs. Also, though "Set Info" is not a button, it merits the instructor's close attention and use.

Conclusion

Given that homework is an important part of the teaching-learning process in mathematics and given that human nature is what it is, the typical college student does not spend enough time doing, checking, and reflecting on homework to learn the subject well. WeBWorK is not an ideal solution to the pedagogical disconnect between the instructor's efforts to have students master the material sufficiently well and the typical student's approach to homework, but it is a real and sensible partial solution. Until something better comes along, we highly recommend WeBWorK for mathematics homework for traditional and online courses.

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